(12) UK Patent Application (19) GB (11) 2 313 391 (13) A

(43) Date of A Publication 26.11.1997

(21) Application No 9708956.9

(22) Date of Filing 01.05.1997

(30) Priority Data
(31) 08642824 (32) 03.05.1996 (33) US

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(51) INT CL^6
E21B 7/08 29/06

(52) UK CL (Edition O)
E1F FCU

(56) Documents Cited
GB 2303158 A GB 2299105 A US 5484021 A

(58) Field of Search
UK CL (Edition O) E1F FCU
INT CL^6 E21B
Online: WPI

(54) Whipstock accelerator ramp

(57) A whipstock 44 guides a cutting tool 32 within a cased borehole 9. The whipstock 44 has a profiled guide surface 28, for guiding the cutting tool 32, which includes a plurality of ramps at differing inclines to the wellbore axis. The guide surface has a starter surface 45 preferably at 15°, a vertical surface 46 parallel to the wellbore axis, an initial ramp surface preferably at 3° a "kick out" surface preferably at 15° and a subsequent ramp surface preferably at 3°. The "kick out" surface is located at the point that the centre of the cutting tool 32 reaches the inside diameter of the wall of the casing thereby more quickly moving the centre point of the cutting tool 32 across the wall of the casing. The vertical surface 46 has a length equal to the distance between mills 32 and 33.

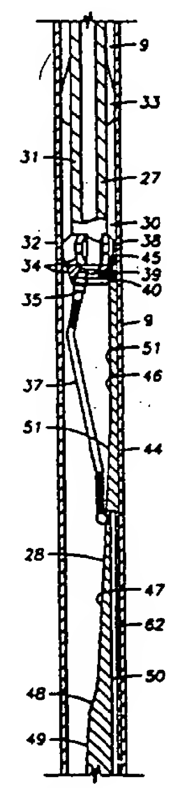


FIG. 3A

GB 2 313 391 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

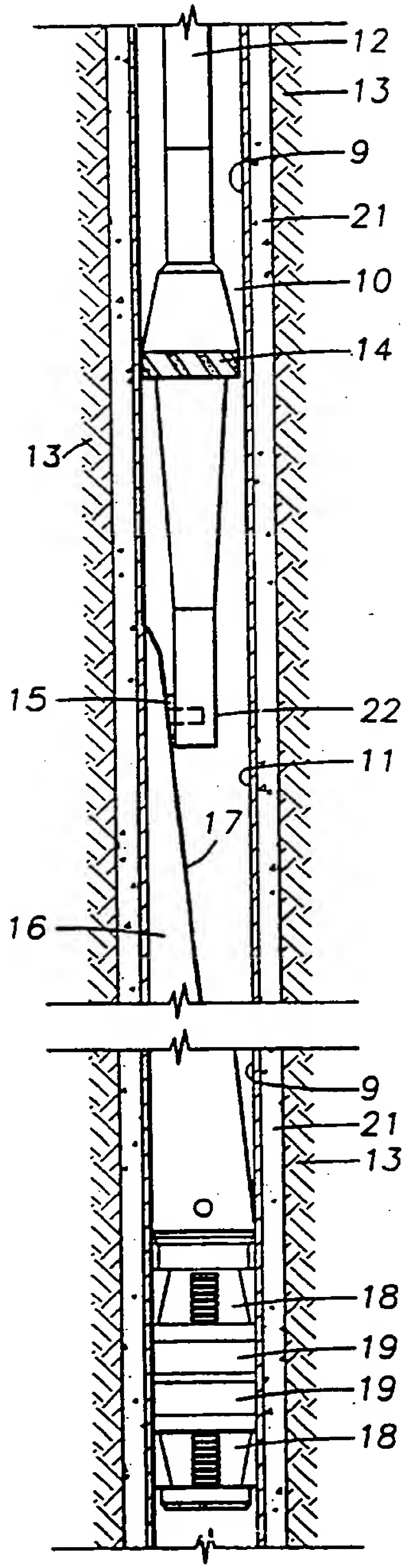


FIG. 1
(PRIOR ART)

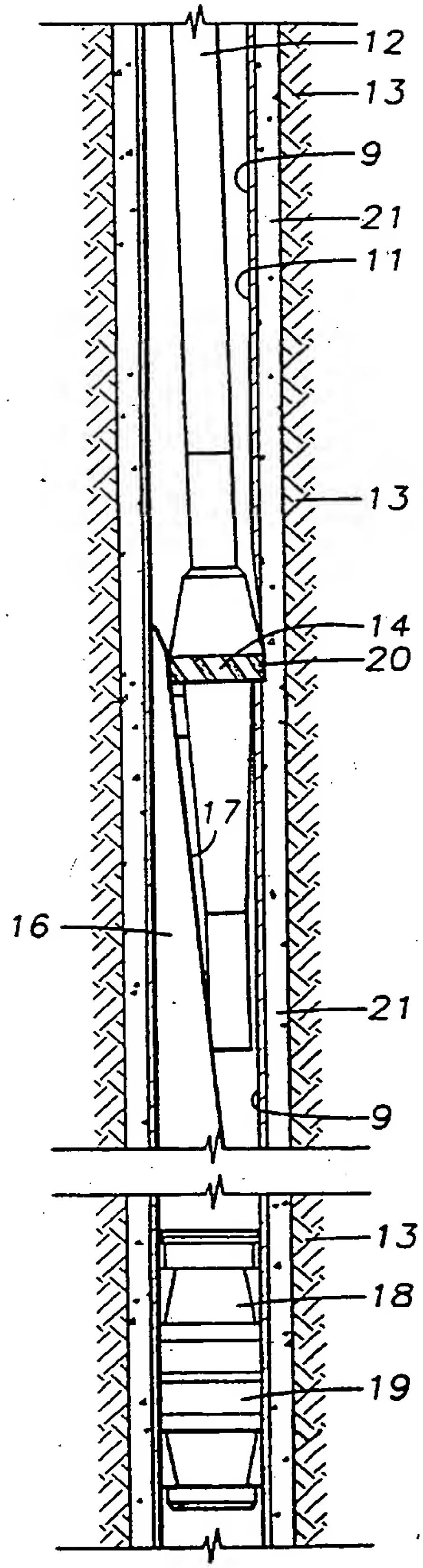


FIG. 2
(PRIOR ART)

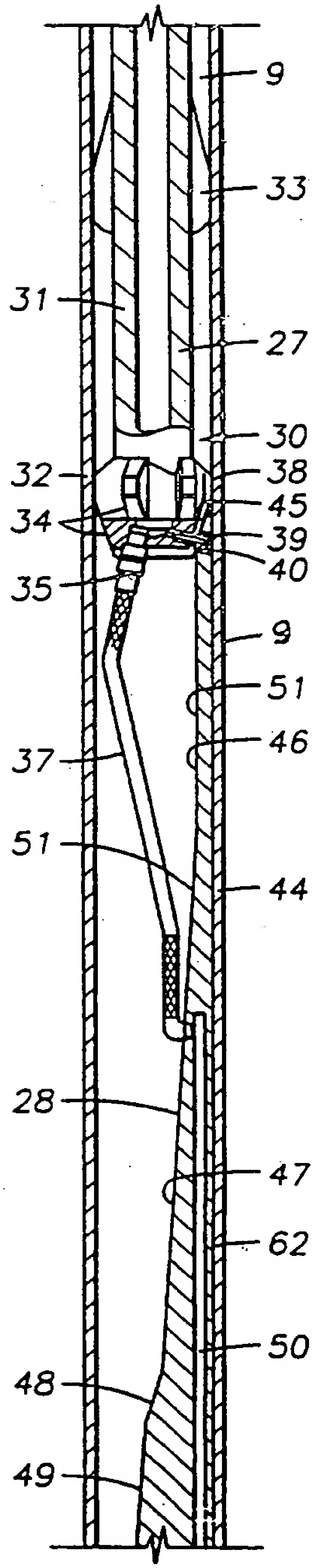

9
33
31
27
30
32
38
45
34
39
40
35
9
51
46
37
51
44
28
47
62
50
48
49

FIG. 3A

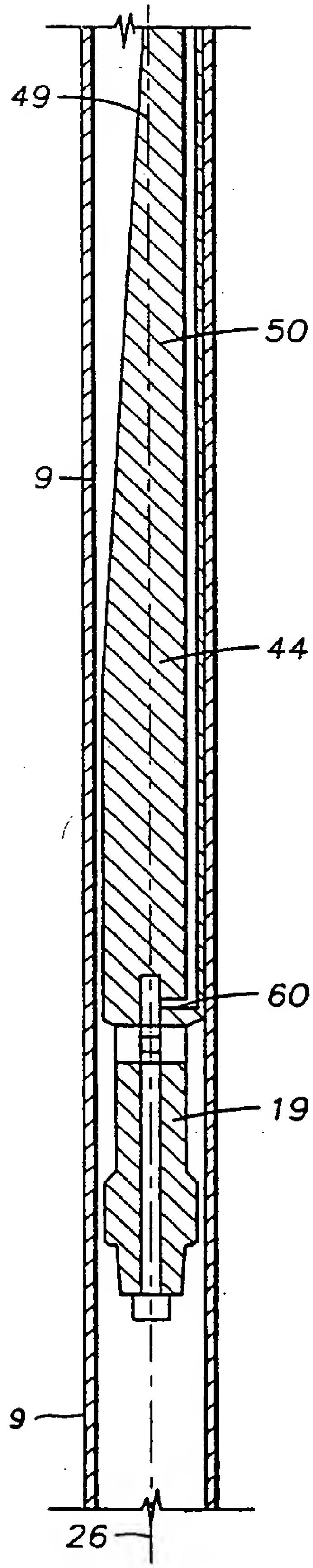

49
50
9
44
60
19
9
26

FIG. 3B

FIG. 4

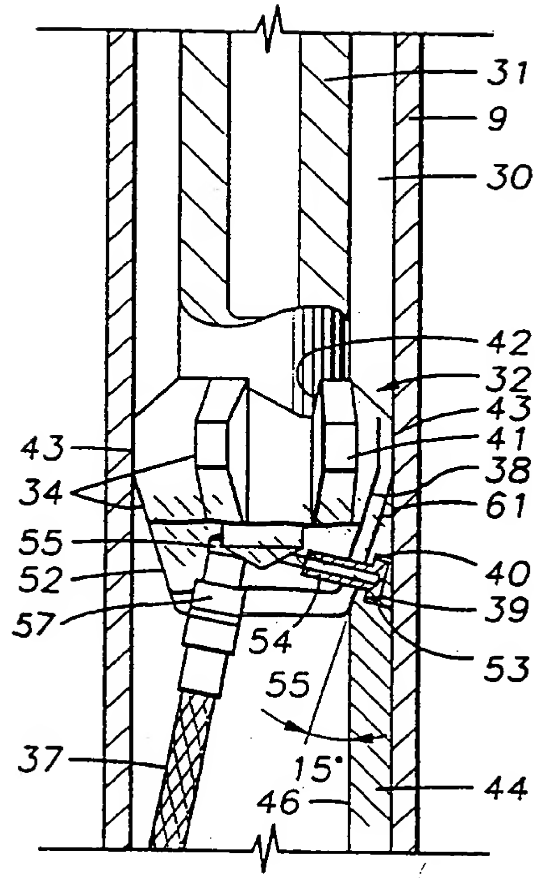
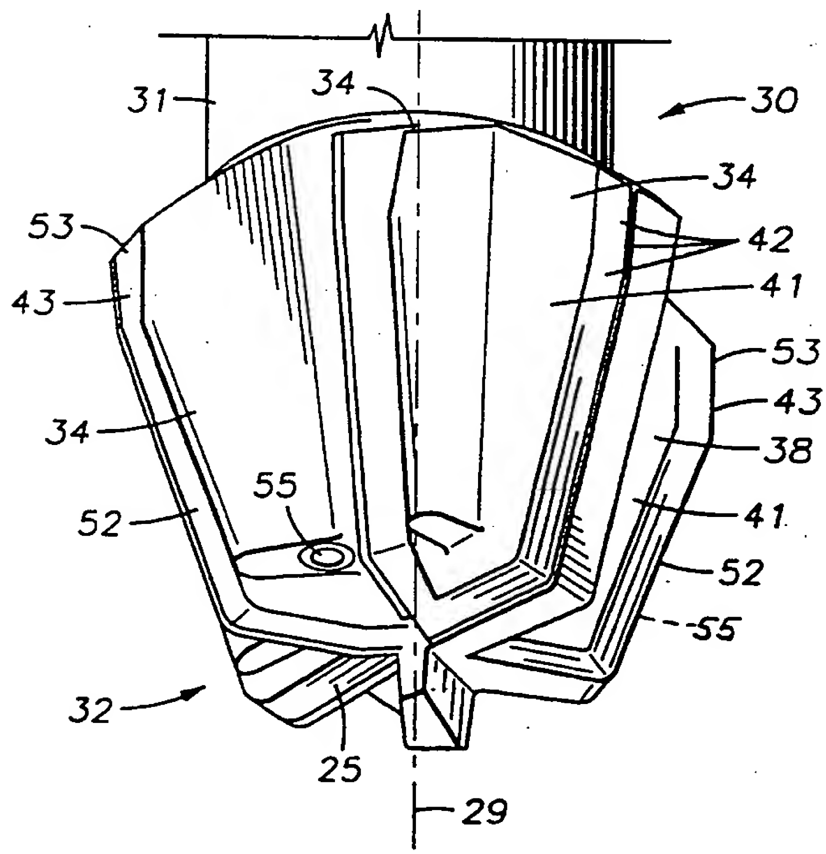

31
9
30
42
32
43
41
38
61
40
39
53
44
43
34
55
52
57
54
55
15°
37
46

FIG. 5


30
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42
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41
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38
34
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32
25
29

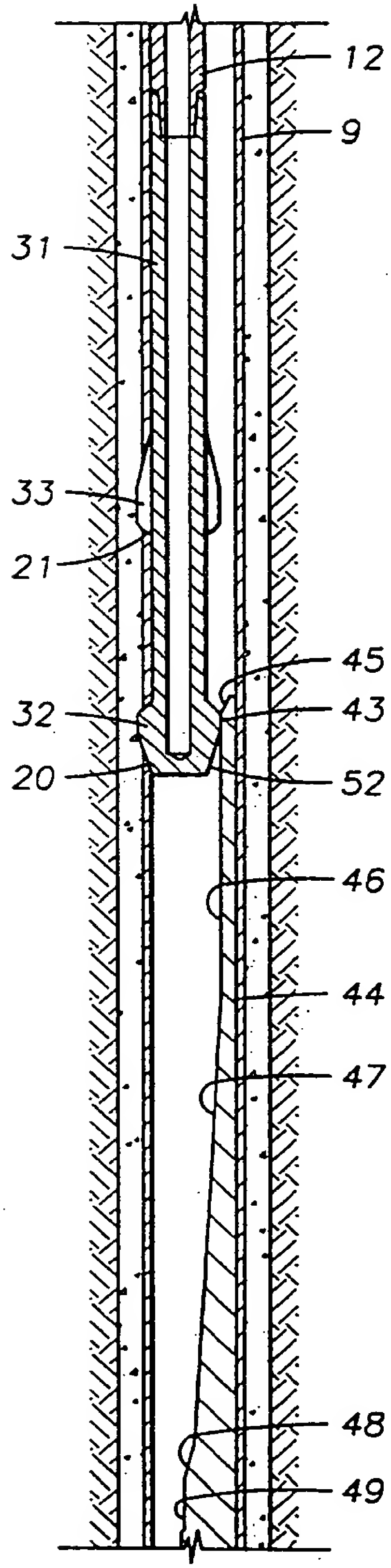

FIG. 6B

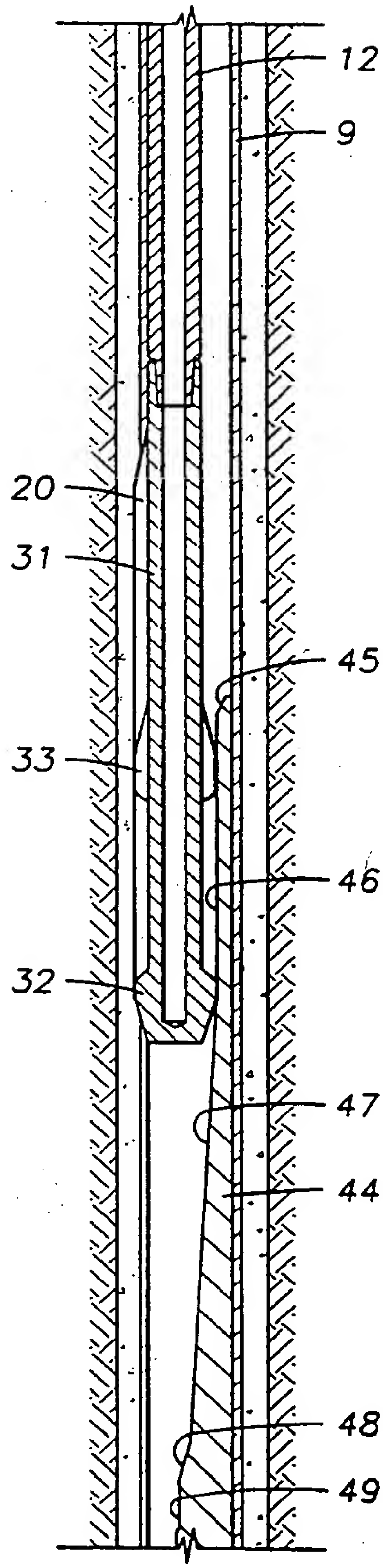

FIG. 7B

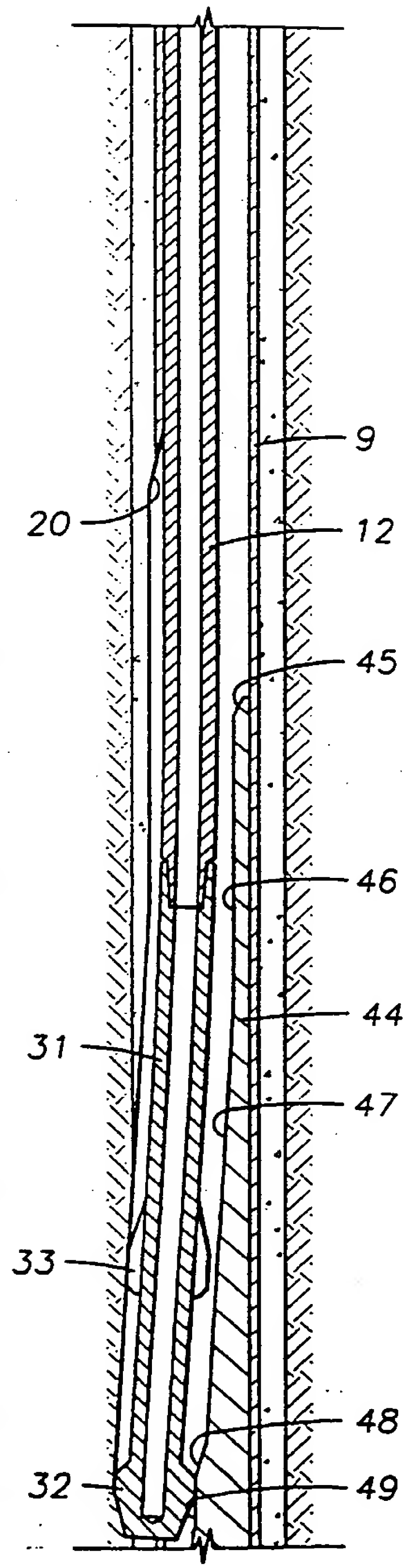

FIG. 8B

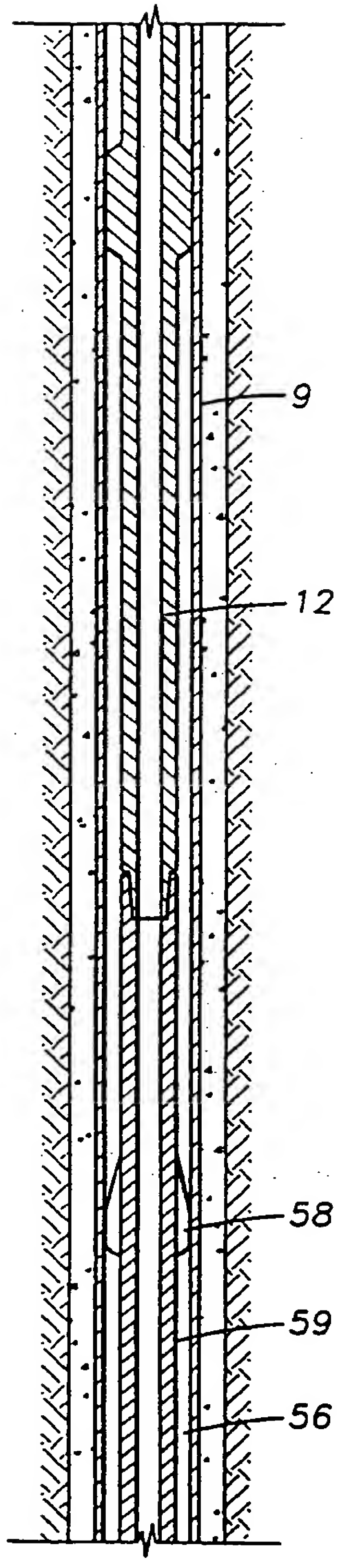

FIG. 9A

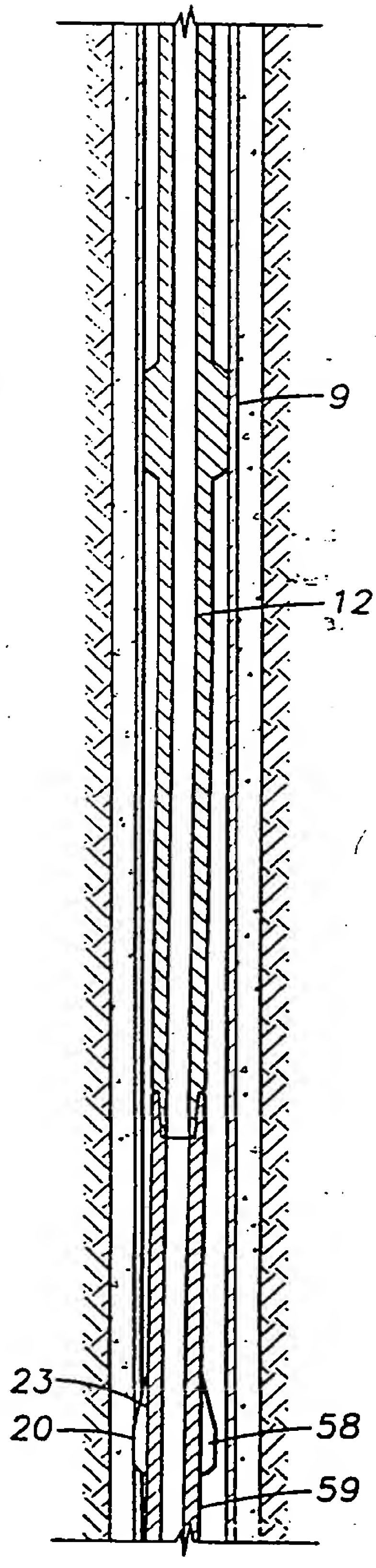

FIG. 10A

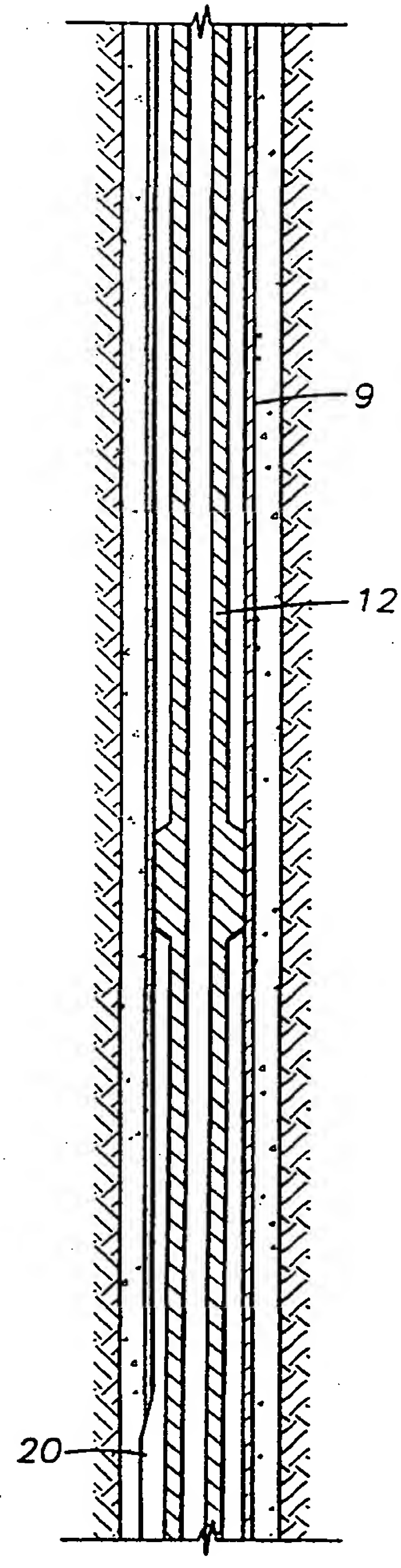

FIG. 11A

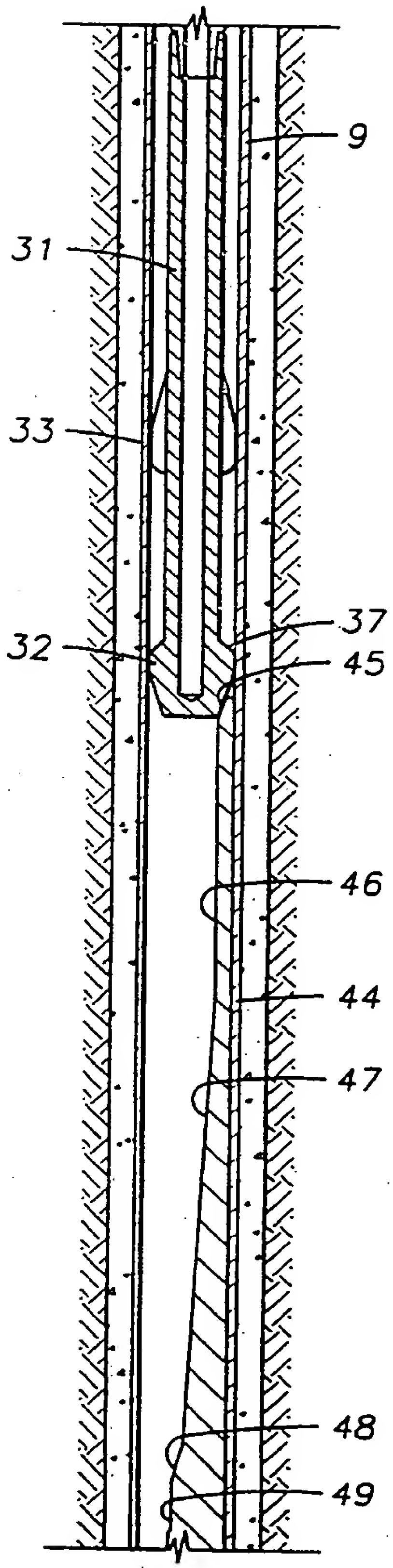

FIG. 9B

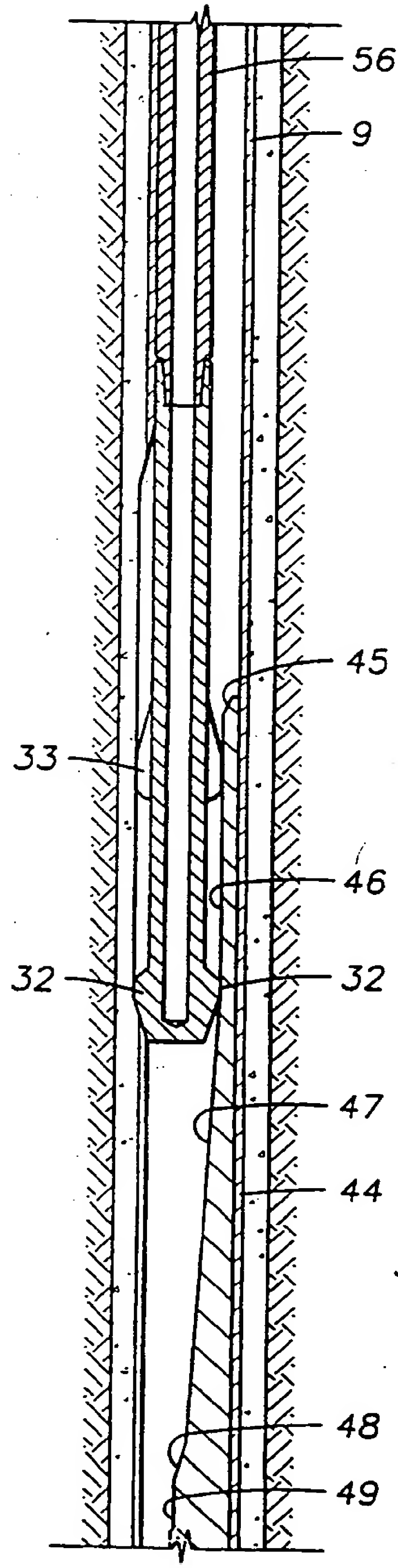

FIG. 10B

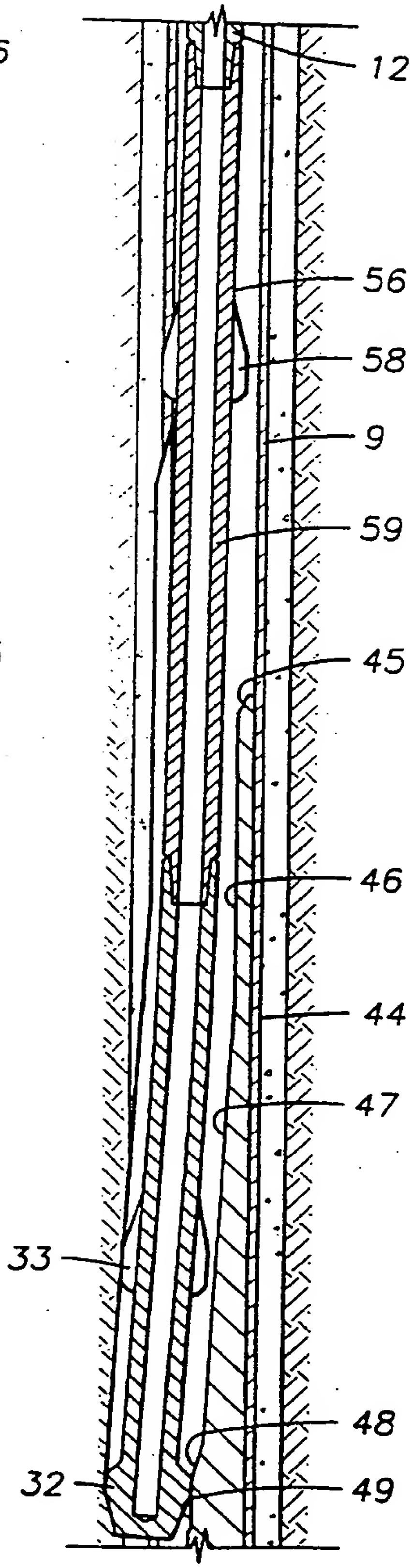

FIG. 11B

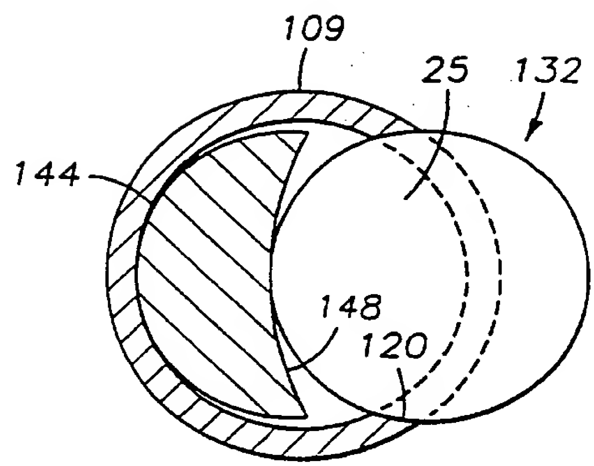

FIG. 13

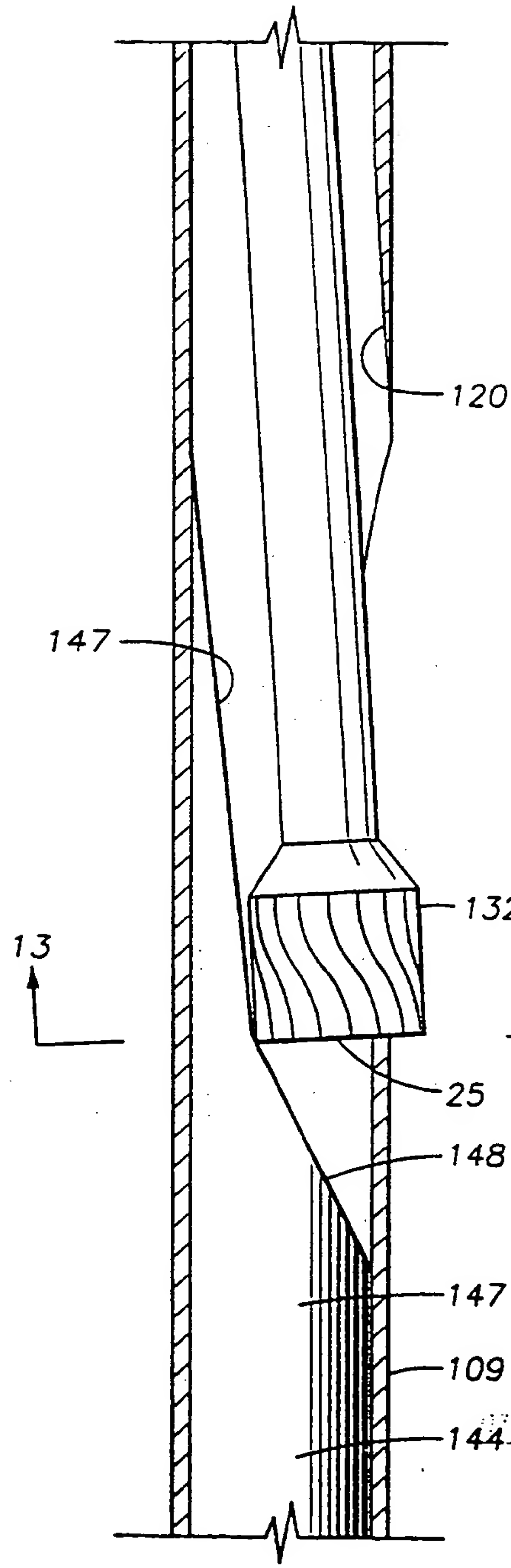

FIG. 12

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WHIPSTOCK ACCELERATOR RAMP

The present invention relates to a whipstock for guiding a cutting tool within a casing, and to apparatus for cutting a window in a casing disposed within a well, and further to a method of drilling a window in a casing disposed in a well.

In embodiments, the present invention relates to a method and apparatus for drilling a secondary borehole from an existing borehole in geologic formations, and more particularly to a whipstock for guiding a mill into the wall of the existing borehole, and still more particularly to a whipstock having a guide surface with a ramp for accelerating the passage of the centre of the mill across the wall of the casing.

Traditionally, whipstocks have been used to drill a deviated borehole from an existing earth borehole. The whipstock has a ramp surface which is set in a predetermined position to guide the drill bit on the drill string in a deviated manner to drill into/the side of the earth borehole. In operation, the whipstock is set on the bottom of the existing earth borehole, the set position of the whipstock is surveyed, the whipstock is properly oriented for directing the drill string in the proper direction, and the drilling string is lowered into the well into engagement with the whipstock causing the whipstock to orient the drill string to drill a deviated borehole into the wall of the existing earth borehole.

Previously drilled and cased wellbores, for one reason or another, may become non-productive. When a wellbore becomes unusable, a new borehole may be drilled in the vicinity of the existing cased borehole or, alternatively, a new borehole may be sidetracked from or near the bottom of a serviceable portion of the cased borehole. Sidetracking from a cased borehole is also useful for developing multiple production zones.

Sidetracking is often preferred because drilling, casing and cementing the borehole is avoided. This drilling procedure is generally accomplished by either milling out an entire section of pipe casing followed by drilling through the side of the now exposed borehole, or by milling through the side of the casing with a mill that is guided by a wedge or "whipstock" component.

Drilling a side tracked hole through a pipe casing made of steel is difficult and often results in unsuccessful penetration of the casing and destruction of the whipstock. In addition, if the window is improperly cut, a severely deviated dog leg may result, rendering the sidetracking operation unusable.

Several patents relate to methods and apparatus to sidetrack through a cased borehole. US-A-4266621 describes a diamond milling cutter for elongating a laterally directed opening window in a well pipe casing that is set in a borehole in an earthen formation. The mill has one or more eccentric lobes that engage the angled surface of a whipstock and cause the mill to revolve on a gyrating or non-fixed axis and effect oscillation of the cutter centre laterally of the edge thus enhancing the pipe cutting action. A first stage begins a window in the pipe casing, a second stage extends the window through use of a diamond milling cutter and a third stage with multiple mills elongates and extends the window.

US-A-5109924 teaches a one trip window cutting operation to sidetrack a wellbore. A deflection wedge guide is positioned behind the pilot mill cutter and spaced from the end of a whipstock component. The shaft of the mill cutter is retained against the deflection wedge guide such that the milling tool frontal cutting surface does not come into contact with the ramped face of the whipstock. In theory, the deflection wedge guide surface takes over the guidance f the window cutting tool without the angled ramp surface of the whipstock being destroyed.

US-A-5455222 teaches a combination whipstock and staged sidetrack mill. A pilot mill spaced from and located on the common shaft above a tapered cutting end is, at its largest diameter, between 50 percent and 75 percent of the final sidetrack window diameter. A surface of a second stage cutter positioned on the same shaft above the pilot mill is, at its smallest diameter, about the diameter of the maximum diameter of the pilot mill, and is, at its largest diameter, at least 5 percent greater in diameter than the largest diameter of the pilot mill.

Once the window mill is centred on the wall of the casing, further cutting becomes difficult because of the reduced rotation of the cutting edges at the centre of the tapered window mill. At the exact centre of the tapered window mill, there is essentially zero rotation. Thus, in the prior art, it took a long cutting time to have the window mill move and cut past its centre line. On a standard 3° whip face, it often took a drilling length of plus or minus ten inches (say 25cm) to have the centre line of the window mill cross the wall of the casing. Very slow drilling progress is made during this period of time because the window mill is attempting to cut the wall of the casing with essentially zero rotation at the centre of the window mill.

The present invention overcomes the deficiencies of the prior art.

According to a first aspect of the present invention, there is provided a whipstock for guiding a cutting tool within a casing, the whipstock comprising: a body having an axis; and, a guide surface on said body adapted for guiding engagement with a cutting tool, said guide surface including a first taper with a first angle to said axis and a second taper with a second angle to said axis, said second angle being greater than said first angle.

According to a second aspect of the present invention, there is provided an apparatus for cutting a window in a casing disposed within a well, the apparatus comprising: a

cutting assembly having a cutting assembly axis and including a first cutting member with a first cutting surface forming a first cutting angle with said cutting assembly axis; and, a guide member having a guide member axis and including a guide surface with a first tapered surface having a first angle with said guide member axis and a second surface having a second angle with said guide member axis; said first cutting surface engaging said first tapered wedge surface for deflecting said cutting member into the casing and then said first cutting surface engaging said second surface as the centre of said first cutting member reaches the inside diameter of the casing.

According to a third aspect of the present invention, there is provided a method of drilling a window in a casing disposed in a well, the method comprising the steps of:

releasably connecting a starter cutting member to one end of a whipstock;

engaging a cutting surface on the starter cutting member with an initial surface on the whipstock;

disposing the starter cutting member and whipstock within the casing;

disconnecting the starter cutting member from the whipstock;

deflecting the starter cutting member into engagement with the casing;

engaging the cutting surface on the starter cutting member with a subsequent surface on the whipstock; and,

passing the centreline of the starter cutting member from the inside diameter to the outside diameter of the casing.

According to a fourth aspect of the present invention, there is provided a method of drilling a window in a casing disposed in a well, the method comprising the steps of:

lowering a milling assembly releasably connected to a whipstock assembly into the casing;

anchoring the whipstock assembly within the casing;

disconnecting the milling assembly from the whipstock assembly;

lowering and rotating the milling assembly having at least one cutting member;

engaging a cutting surface on the cutting member with an initial surface on the face of the whipstock of the whipstock assembly;

deflecting the cutting member into engagement with the casing;

guiding the cutting member along on the face of the whipstock until the centre of the cutting member reaches the inside diameter of the casing;

engaging the cutting member with a steep wedge surface;

deflecting the cutting member against the casing until the centre of the cutting member passes to the outside diameter of the casing; and,

guiding the cutting member along on the face of the whipstock until the window is cut.

According to a fifth aspect of the present invention, there is provided a whipstock for deflecting a cutting tool into the wall of a casing, comprising: a body; and, a guide surface on said body adapted for engagement with the cutting tool, said guide surface having an accelerator ramp for enhancing the degree of deflection of a cutting tool as the centre of the cutting tool reaches the wall of a casing.

According to a sixth aspect of the present invention, there is provided a whipstock for guiding a cutting tool within a casing, the whipstock comprising a body having an axis, the body having a plurality of contiguous guide surfaces on one side for guiding a cutting tool within a casing in which a window is to be cut, said guide surfaces including in sequence: a first surface with a first angle to said axis for guiding a cutting tool into initial cutting engagement with and partly through a wall of a casing; a second surface substantially parallel to said

axis for guiding the cutting tool during cutting of the wall of the casing; a third surface with a third angle to said axis for guiding the cutting tool further out of the casing; and, a fourth surface with a fourth angle to said axis for kicking said cutter out through said casing wall, said fourth angle being greater than the third angle.

Thus, in embodiments, a whipstock forms a ramp which acts as a bearing surface for laterally forcing the starter mill into the pipe casing. The face of the ramp of the whipstock includes an accelerator ramp which changes the rate of deflection of the mill as the centre of the mill reaches the inside diameter of the wall of the pipe casing. The accelerator ramp preferably has an angle of 15° with the axis of the whipstock.

It is preferred that the window mill includes tapers that conform to most of the ramp angles formed by the whipstock. For example, the largest diameter of the window mill may form a 3° cutting section matching the 3° section of the whipstock above the accelerator ramp. The tapered end of the window mill preferably has an angle of 15° which is parallel to the 15° formed by the accelerator ramp. These matching angulations minimize damage to the whipstock face during the window cutting process thereby assuring a successfully cut window in the casing of the borehole.

An advantage of the present invention over the prior art is the use of the acutely angled accelerator ramp section at a point along the ramped whipstock surface when the centre of the window mill reaches the inside diameter of the wall of the casing resulting in a slowdown in the window cutting operation. The "kick out" ramp more quickly moves the tapered window mill past this phase of the window cutting process thus speeding up the completion of the sidetrack window.

Another advantage of the present invention over the prior art is the use of a tapered window mill with a surface contour matching the angle of the accelerator ramp

such that the mill is forced to more quickly pass over the wall of the casing.

A still further advantage of the present invention over the prior art is the formation of angled and parallel ramp surfaces formed on the whipstock to facilitate and enhance the cutting action of both the window mill and the second mill, upstream of and spaced from the window mill.

Other objects and advantages will be apparent from the following description.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a partial cross-sectional view of a prior art sidetracking operation depicting setting an anchor for a typical whipstock sidetracking system in a cased borehole;

Figure 2 is a partial cross-sectional view of a first stage of the prior art sidetracking operation illustrating cutting a window section in a pipe casing with a typical starter mill;

Figures 3A and B are a partial cross-section of a preferred embodiment of the invention whereby the top of the whipstock matches the taper of the window mill;

Figure 4 is an enlarged partial cross-section of the tapered window mill illustrating the hollow shear pin attaching the tapered window mill to the parallel ramped surface formed adjacent the top of the whipstock;

Figure 5 is a perspective view of the tapered window mill with chip breaking cutter elements attached to the cutting face of each blade of the window mill;

Figures 6A and B are a partial cross-section of the one trip sidetrack window cutting apparatus wherein the mill is sheared from the top of the whipstock and is moved laterally through the casing by 15° ramp angle formed in the top of the whipstock;

Figures 7A and B are a partial cross-section of the window mill and upstream "tear drop" cutter cutting the

window in the pipe casing. The ramp section immediately below the 15° ramp formed in the whipstock is parallel to the axis of the pipe casing while the tear drop cutter completes its initial cut in the window from its entry into the casing to its intersection with the cut made by the tapered window mill;

Figures 8A and B are a partial cross-section of the window mill contacting a second "kick out" ramp formed in the 3° ramp portion of the whipstock, the kick out ramp serving to force the window mill out of the casing so that it will complete the window more efficiently;

Figures 9A and B are a partial cross-section of an alternative window cutting apparatus identical to the apparatus shown with respect to Figures 6 through 8 with the exception of a "watermelon" mill positioned upstream of the tear drop mill;

Figures 10A and B are a partial cross-section of the alternative apparatus illustrating the watermelon mill starting its cut into the pipe casing above the window started by the downstream mills;

Figures 11A and B are a partial cross-section of the alternative apparatus after the window, tear drop and watermelon mills have cut an elongated window in the casing;

Figure 12 is a partial cross-section of an alternative whipstock with a "kick out" ramp in the 3° ramp portion; and,

Figure 13 is a view taken through 13-13 of Figure 12.

Referring now to the prior art of Figure 1, the casing sidetrack system generally designated as 10 consists of a drill collar 12 attached to a starter mill 14. The starter mill 14 is affixed to the end of the whipstock 16 through a shear bolt block 15. The whipstock 16 has an anchor 18 attached to the downhole end of the whipstock. The entire assembly 10 is tripped into a cased borehole 9. After the sidetracking system reaches a desired depth in the borehole, the whipstock 16 is oriented to a desired

sidetrack angulation and set or anchored in the steel pipe casing 11. Casing 11 generally is made of steel but may be made of various other materials such as fibreglass as for example.

With reference to the prior art of Figure 2, once the system 10 is properly oriented and set in the casing 11, the starter mill 14 is released from the end of the whipstock 16 by breaking the solid shear pin 22 secured to the bolt block 15. The starter mill 14 is subsequently directed into casing 11 by shear bolt block 15 along ramped surface 17 formed by whipstock 16. The starter mill 14 then mills a window 20 through the wall of the casing 11. After the starter mill 14 begins the window 20, it is tripped out of the cased borehole 9.

Turning now to the preferred embodiments represented in Figure 3 through 11, Figure 3 illustrates a one trip mill assembly generally designated as 30 and a whipstock assembly generally designated as 60. The mill assembly 30 includes a tapered window mill generally designated as 32. The mill 32 is attached to the bottom end of a shank or shaft 31. Upstream and spaced from the window mill is, for example, a second mill 33 also mounted to the shaft 31. The upstream end of the shaft 31 is either threadably connected to a drill string or threaded to another subassembly (see Figures 9 through 11). A tubular member 27 may form the shaft 31 on which mills 32 and 33 are mounted. Tubular member 27 may include a lower reduced diameter portion on which mill 32 is disposed with mill 33 being disposed on the full diameter of tubular member 27. This reduction in diameter provides flexibility between mills 32, 33 during the milling process.

A third mill may be mounted to a shaft upstream of second mill 33. The third mill is desirable in some circumstances and will be discussed in detail with respect to Figures 9, 10 and 11.

The window mill 32 includes a plurality of blades, such as blade 38, having a particular cutting profile which

forms three cutting surfaces. The lower tapered end 52 of the window mill 32 is tapered, for example, 15° with respect to the axis 29 of the casing 11 in the borehole (more clearly shown in Figure 4). The taper may be in the range of 1 to 45 degrees. The end surface 45 of the whipstock, generally designated as 44, is profiled (angle 15°) to match the angle of the lower tapered end 52 of the window mill (15 degrees). A shear pin 39 anchors the tapered window mill 32 through a connection in blade 38 of the mill 32 to profiled surface 45 of the whipstock 44.

Window mill 32 further includes a medial cutting surface 43 with a reduced taper of 3° which conforms to the 3° tapers on the profiled ramp surface 28 of the whipstock 44. The taper of surface 43 may be in the range of 1 to 15 degrees. A final full gauge cutting surface 53 extends vertically above medial cutting surface 43 and is parallel to the axis 29. The opposite end of the whipstock is secured to a, for example, hydraulically actuated anchor (not shown). A typical anchor is shown in US Patent Application Serial No. 572,592 filed December 14, 1995, incorporated herein by reference.

The assembly 30 is lowered into cased borehole 9 to a predetermined depth. The whipstock 44 is then rotated to a desired sidetrack direction followed by hydraulically actuating the anchor (not shown) by directing drilling fluid or "mud" down the drill string 12 under high pressure through flex conduit 37 connected to a coupling 57 on the end of the window mill 32. Coupling 57 includes a weakened area therearound such as a reduced diameter portion allowing coupling 57 to break cleanly from the mill 32. The pressurized fluid then enters conduit 50 formed in the whipstock 44 and from there passes to a connecting member 19 and then to the anchor to extend the pipe gripping elements within the anchor (not shown).

The backside 62 of the whipstock 44, especially adjacent the end 61 of the whipstock 44, is contoured to

conform to the inside diameter of the pipe casing 11, for stability of the top of the whipstock 44.

The whipstock 44 includes a profiled ramp surface 28 having a curved or arcuate cross section and multiple surfaces, each forming its own angle with the axis 26 of whipstock 44. Profiled ramp surface 28 includes a starter surface 45 having a steep angle preferably 15°, a vertical surface 46 preferably parallel to the axis 26, an initial ramp surface 47 having a standard angle preferably 3°, a "kick out" surface 48 having a steep angle preferably 15°, and a subsequent ramp surface 49 having a standard angle preferably 3°. It should be appreciated that these angles may vary. For example, the starter ramp surface 45 may have an angle in the range of 1 to 45 degrees, and preferably in the range of 2 to 30 degrees, and still more preferably in the range of 3 to 15 degrees, and most preferably 15 degrees. The vertical surface 46 has a length approximately equal to or greater than the distance between mills 32 and 33.

When the window mill 32 is full gauge, the "kick out" ramp surface 48 begins at that point on the initial 3° ramp surface 47 where the thickness of the ramp surface 47 is approximately equal to the radius of the whipstock 44. In other words, the radial distance between that point on surface 47 and the inside diameter of the wall of the casing 11 should be approximately the same or slightly longer than the radius of the window mill 32. This ensures that "kick out" ramp surface 48 will increase the rate of deflection of the window mill 32 just before the centre 25 of window mill 32 reaches the inside diameter of the wall of the casing 11. The "kick out" ramp surface 48 forms an accelerator ramp which exerts a lateral force to the window mill 32 and greatly increases the rate of deflection of the window mill 32 into the wall of the casing 11. Although the preferr d angle of "kick out" surface 48 is 15 degrees, the angle may be from 10 to 45 degrees. It should be appreciated that the kick out ramp surface 48 may be used

in constant angle whipstocks such as a whipstock having a standard ramp surface of, for example, 2 to 3 degrees, with the "kick out" ramp surface having a substantially greater ramp angle located at approximately the mid-whip position of the whipstock thereby creating a jog or deviation in the otherwise constant angle of the whipstock. The use of the "kick out" ramp surface 48 allows the design of the window mill 32 to incorporate a lighter dressing which will increase formation ROP (rate of penetration).

Referring now to the enlarged Figure 4, once the anchor is set, further sufficient tension force imparted to the drill string breaks the shear pin 39 freeing the tapered window mill 32. The relatively steep profiled angle (15 degrees) formed in surface 45 of the whipstock 44 immediately provides a lateral force to the tapered end 52 of the mill 32 thus forcing the rotating mill 32 into the interior of the wall of the pipe casing 11 to start forming a first window 20A in the pipe casing 11. The upstream second mill 33, which may be tear drop in shape, is also forced into the wall of the pipe casing 11 thereby simultaneously cutting a second window 20B above the first window 20A formed by the window mill 32. The surface 46 formed by the whipstock 44 below angled surface 45 is preferably parallel to the axis of the pipe casing 11 while the window mill 32 and the second mill 33 cut simultaneous windows 20A and B (Figure 6).

Surface 45 is heavily hardfaced with, for example, a composite tungsten carbide material 51 metallurgically applied to the ramp surface. One preferred hardfacing is Colmonoy 88 manufactured by Wall Colmonoy and has a hardness of RC 58-64. Moreover, the entire profiled ramp surface 28 of the whipstock 44, exposed to the cutting action of the mills, may be hardfaced.

The perspective of the tapered window mill 32 consists of blades 34, each blade having, for example, a multiplicity of cutting elements such as tungsten carbide cutters 42 with "chip breakers" formed on the face of the

cutters. The chip breakers on the face of each cutter serve to break up the curled cuttings resulting from the window mill 32 cutting through the pipe casing 11 so that the cuttings may be transported up the drill string annulus by the mud circulated through the drill string. Without the chip breaker, the continuous cuttings create a "rats nest" downhole and cannot be easily removed.

These highly effective cutters are manufactured by Rogers Tool Works, Rogers, Arkansas and are known as Millmaster.

It would be obvious to utilize natural or polycrystalline diamond cutters (not shown) on the cutting blades 34 of the tapered window mill 32 without departing from the scope of this invention.

Blade 38 immediately adjacent the parallel surface 45 of whipstock 44 is preferably wider to accommodate the shear bolt 39 threaded into the blade 38. The head of the shear bolt 53 is seated in the end of the whipstock 61 and the threaded shank 54 is threaded into blade 38. The shank 54 of the shear bolt is preferably hollow/so that, once the bolt 39 is sheared, the shank 54 serves as a nozzle extension for nozzles 55 positioned at the base of shank 54 and at the entrance to conduit 37 that directs fluid to the whipstock anchor (not shown).

However, a shear bolt with a solid shank could alternatively be used, though a nozzle would not be provided on shearing the bolt in this case.

With specific reference to Figure 7, once the upstream window 20B (cut by the second mill 33) merges with the downstream window 20A started by the window mill 32, cutting forces are lessened. The ramp surface 47 formed by the whipstock 44 below the parallel surface 46 then transitions into a ramp with a 3° angle.

Referring now to Figure 8, when the centre of the window mill 32 starts cutting at the inside diameter of the wall of the casing 11 as the window milling apparatus progress s down the whipstock 44 and out through the window

20 cut into the pipe casing 11, the cutting or pipe milling action is slowed considerably. At this point the "kick out" ramp 48 (15° as compared to the 3° ramp surface 47) "kicks" the window mill 32 out through the casing 11 for more efficient milling of the casing 11. Once past this part of the window milling process, the ramp 49 below the kick out ramp 48 reverts back to the standard 3° ramp angle surface 49.

An alternative embodiment is illustrated in Figures 9 through 12. A second subassembly generally designated as 56 is positioned intermediate mill assembly 30 and the drill string 12. A third mill 58, such as a watermelon mill, is spaced between the male and female ends of the shank or shaft 59 (Figure 9).

Figure 10 illustrates the third mill 58 having generally the same diameter as the window mill 32 and second mill 33 and which serves to lengthen the window 20 penetrating the casing 12 above the window 20 cut by the window and second mills 32, 33. It is preferred that all three mills 32, 33 and 58 be full gauge.

The third mill 58 also serves to dress the window opening 20 as shown in Figure 11 for easy transition of the following side track drill bit assembly.

The elongation of the window 20 by the watermelon mill 58 is desirable to facilitate sidetracking drill bit assemblies that are relatively stiff and the angle of the side track borehole is slight. A longer window then would be necessary.

Where the side track angle is more severe and the drill bit side track assembly is relatively limber, a shorter window will suffice and the watermelon assembly 56 is omitted from the window cutting apparatus as is shown with respect to Figures 3 through 8.

Upon assembly, mill assembly 30 is connected to whipstock assembly 60 by shear bolt 39 with the lower tapered end 52 of window mill 32 being engagingly disposed

against starter surface 45. Further, hydraulic hose 37 is connected to assemblies 30, 60.

In operation, the whipstock assembly 60 and mill assembly 30 are connected to the lower end of a drill string 12 and lowered into cased borehole 9 as shown in Figures 9A and B. Once the desired depth is reached for the secondary or deflection bore, the whipstock assembly 60 is aligned and oriented within the cased borehole 9 and the anchor is set thereby anchoring the whipstock assembly 60 within the cased borehole 9 at the desired location and orientation. Tension is then pulled on drill string 12 to shear the shear bolt 39.

The mill assembly 30 is then rotated and lowered on the drill string 12. The complementary lower tapered end 52 on the rotating window mill 32 cammingly and wedgingly engages starter surface 45 on whipstock 44 thereby causing the window mill 32 to kick out and engage the wall of the casing 11 thereby forcing the cutting elements 34 into milling engagement. As the window mill 32 rotates and moves downwardly, the window mill 32 continues to be deflected out against the wall of the casing 11 and eventually punches through the wall of the casing 11. It is important that the starter surface 45 and its centre line match that of the initial surface 52 on the window mill 32. The angle of tapered end 52 and starter surface 45 may be up to 45°.

Once initial punch out has been achieved, weight on the drill string 12 is required to push the window mill 32. It is the "punch through" of the window mill 32 that is the most important cutting. Once the window mill 32 punches through the wall of the casing 11, a ledge is created allowing the whipstock 44 to then guide the mill assembly 30 through the window 20 cut in the wall of the casing 11.

This initial guidance of the starter surface 45 and the hard facing 51 ensures that the whipstock 44 is not damaged by the window mill 32 and that the window mill 32 properly initiates the required window cut. It is

important to deflect the window mill 32 away from the ramp surface of the whipstock 44 to avoid the window mill 32 from milling the whipstock 44.

Referring now to Figures 10A and B, once the initial punch out is made through the wall of the casing 11 by the window mill 32, the window mill 32 has passed the starter surface 45 and is adjacent the straight surface 46 which allows the mill 32 to run along a straight track. Once the window mill 32 moves past the starter surface 45, window mill 32 continues to mill the wall of the casing 11 while the second mill 33 expands the window in the wall of the casing 11 previously cut by the window mill 32. As the second mill 33 follows behind the window mill 32 and begins to cut into the wall of the casing 11, there is formed an uncut portion of the casing 11 between the two mills 32, 33 which has not yet been milled. As the window mill 32 is lowered downwardly adjacent to straight surface 42, the second mill 33 cuts the unmilled portion of casing 11 which extends between mills 32, 33.

If the second mill 33 is deflected into the casing 11, then that portion of tubular member 27 between the window mill 32 and pilot mill 33 may engage the uncut portion of the casing wall which has not yet been milled out. If the window mill 32 maintains the steep angle of the starter surface 45, it is possible that that portion will engage the uncut portion of the wall of the casing 11 and prevent the mills 32, 33 from cutting the wall of the casing 11. It is possible that the mill assembly 30 could bind and hinder further milling. This is prevented by straight surface 46 which has a height substantially equal to or greater than the distance between mills 32 and 33.

Upon the window mill 32 moving past the straight surface 46, any uncut portion of the casing wall between the mills 32, 33 has now been cut by the second mill 33. At this point, the medial surface 43 of window mill 32 engages the ramp surface 47 and the window mill 32 is again deflected outwardly against the wall of casing 11 to

enlarge the window 20 and is guided by the surface 47 into the wall of the casing 11 without causing any damage to the whipstock 44. Now that the window mill 32 has punched through the wall of the casing 11, it begins cutting into the cement. The second mill 33 is now passing along the straight surface 46 and cutting the window 20 that has already been started by the window mill 32 to make the window wider. As can be appreciated, watermelon mill 58, following the second mill 33, also begins cutting and widening the window 20 through casing 11. There may be one or more additional watermelon mills above the first watermelon mill 58. The purpose of the watermelon mills is to elongate the top of the window 20 in the casing 11 and clean up the window 20 particularly if there has been a ledge created.

Referring now to Figures 11A and B, upon completing the milling along the surface 47, the casing wall will be underneath the window mill 32 and the centre 25 of the window mill 32 is approaching the inside diameter of casing 11. At this point, the window mill 32 engages kick out surface 48 to assist the crossing of the wall of the casing 11. The steeper angle on surface 48 causes the centre 25 of window mill 32 to more quickly kick out and radially pass from the inside diameter to the outside diameter of the wall of casing 11. The second mill 33 and watermelon mill 58 are following and expanding and clearing the window in the wall of the casing 11. The mill assembly 30 drills faster into the formation once the window mill 32 completely passes the cased wall and into the formation.

The kick out wedge surface 48 is a second steep surface to assist in moving the window mill 32 from the inside diameter to the outside diameter of the wall of the casing 11. When the centre line 25 of the window mill 32 is sitting on the wall of the casing 11, the window mill 32 is essentially at zero rotation. The purpose for the kick out surface 48 is to reduce the drilling time required to cross the wall of the casing 11. The increased angle of

surface 48 allows th window mill 32 to move quickly across the wall of casing 11. By increasing the angle between window mill 32 and whipstock 44, the cutting distance of the window mill 32 is shortened for the centre line 25 of the window mill 32 to cross the wall of the casing 11.

Further, additional weight can be applied to the drill string 12 to increase the force on the window mill 32 and to cause the centre line 25 of the window mill 32 to cross the casing wall more quickly. Once the centre line 25 of the window mill 32 crosses the wall of the casing 11, the window mill 32 goes back to the final three degree surface 49 departure to exit. This reduced drilling time and distance allows significant savings.

Upon the window mill 32 moving past the kick out surface 48, the centre line 25 of window mill 32 has passed outside of the wall of the casing 11 and is creating a diverted path to form a side track through the wall of the casing 11 and a window borehole in the formation. At this point, the medial surface 43 of window mill 32 engages the lower ramp surface 49 and the window mill 32 is deflected laterally to drill the window borehole. The window mill 32 is now being guided by the lower surface 49 into the formation. The window mill 32 in effect drills the window borehole for the drill bit so that the drill bit can get a faster start in drilling the new borehole.

The window 20 is cut substantially the entire length of the whipstock 44. Once the milling or cutting of the window is completed, the drill string 12 and mill assembly 30 are replaced by a standard drilling apparatus for drilling the new borehole.

Turning now to the alternative embodiments of Figures 12 and 13, a whipstock generally designated as 144 has, formed on its 3° ramp surface 147, a kick out ramp 148.

The aggressive angle of the ramp 148 formed in the whipstock guide surface 147 enables the conventional window mill cutter 132 to quickly move beyond that part of the milling process which occurs when the c ntre 25 of the mill

132 is passing over the wall of the casing 109 as heretofore described.

Figure 13 illustrates the window mill 132 passing over the wall of the casing 109 as it progresses through window 120. The window mill 132 need not have a tapered end as does mill 32 in the embodiment of Figures 1-11. This mill 132 may have a leading end with an angle in the range of 0 to 45 degrees.

The ramp angles for ramps 45, 48 and 148 may be from 1° to 45° with respect to the axis of the whipstocks 44 and 144 without departing from the scope of this invention.

Moreover, where parallel surfaces are mentioned such as blade surface 52 formed by tapered mill 32 and ramp surfaces 45, 48 and 148 formed by whipstock 44, these surfaces are considered "substantially" parallel when such surfaces are less than 3° from being exactly parallel.

It should also be noted that the pipe casing 11 lining the borehole 9 may be other than steel.

Moreover, there may not be any casing lining the borehole 9. Many of the unique features of this invention set forth above will still be advantageous in successfully drilling a deviated borehole in an existing earth borehole.

It will of course be realized that various modifications can be made in the design and operation of the present invention without departing from the scope thereof. Thus, while the principal preferred construction and mode of operation of the invention have been explained in what is now considered to represent its best embodiments, which have been illustrated and described, it should be understood that within the scope of the appended claims, the invention may be practised otherwise than as specifically illustrated and described.

CLAIMS

1. A whipstock for guiding a cutting tool within a casing, the whipstock comprising:

a body having an axis; and,

a guide surface on said body adapted for guiding engagement with a cutting tool, said guide surface including a first taper with a first angle to said axis and a second taper with a second angle to said axis, said second angle being greater than said first angle.

2. A whipstock according to claim 1, wherein said second angle is in the range of 10 to 45 degrees with the axis of the whipstock.

3. A whipstock according to claim 2, wherein said second angle is in the range of 10 to 15 degrees with the axis of the whipstock.

4. A whipstock according to any of claims 1 to 3, wherein said guide surface includes a third taper with a third angle to said axis.

5. A whipstock according to claim 4, wherein said first angle equals said third angle.

6. A whipstock according to claim 4 or claim 5, wherein said first angle is substantially three degrees, said second angle is substantially fifteen degrees, and said third angle is substantially three degrees.

7. An apparatus for cutting a window in a casing disposed within a well, the apparatus comprising:

a cutting assembly having a cutting assembly axis and including a first cutting member with a first cutting surface forming a first cutting angle with said cutting assembly axis; and,

a guide member having a guide member axis and including a guide surface with a first tapered surface having a first angle with said guide member axis and a second surface having a second angle with said guide member axis;

said first cutting surface engaging said first tapered wedge surface for deflecting said cutting member into the casing and then said first cutting surface engaging said second surface as the centre of said first cutting member reaches the inside diameter of the casing.

8. Apparatus according to claim 7, wherein said second angle is in the range of 10 to 45 degrees with respect to the axis of the whipstock.

9. A method of drilling a window in a casing disposed in a well, the method comprising the steps of:

releasably connecting a starter cutting member to one end of a whipstock;

engaging a cutting surface on the starter cutting member with an initial surface on the whipstock;

disposing the starter cutting member and whipstock within the casing;

disconnecting the starter cutting member from the whipstock;

deflecting the starter cutting member into engagement with the casing;

engaging the cutting surface on the starter cutting member with a subsequent surface on the whipstock; and,

passing the centreline of the starter cutting member from the inside diameter to the outside diameter of the casing.

10. A method of drilling a window in a casing disposed in a well, the method comprising the steps of:

lowering a milling assembly releasably connected to a whipstock assembly into the casing;

anchoring the whipstock assembly within the casing;

disconnecting the milling assembly from the whipstock assembly;

lowering and rotating the milling assembly having at least one cutting member;

engaging a cutting surface on the cutting member with an initial surface on the face of the whipstock of the whipstock assembly;

deflecting the cutting member into engagement with the casing;

guiding the cutting member along on the face of the whipstock until the centre of the cutting member reaches the inside diameter of the casing;

engaging the cutting member with a steep wedge surface;

deflecting the cutting member against the casing until the centre of the cutting member passes to the outside diameter of the casing; and,

guiding the cutting member along on the face of the whipstock until the window is cut.

11. A whipstock for deflecting a cutting tool into the wall of a casing, comprising:

a body; and,

a guide surface on said body adapted for engagement with the cutting tool, said guide surface having an accelerator ramp for enhancing the degree of deflection of a cutting tool as the centre of the cutting tool reaches the wall of a casing.

12. A whipstock according to claim 11, wherein said accelerator ramp has an angle of 10 to 15° with the axis of the whipstock.

13. A whipstock for guiding a cutting tool within a casing, the whipstock comprising a body having an axis, the body having a plurality of contiguous guide surfaces on one

side for guiding a cutting tool within a casing in which a window is to be cut, said guide surfaces including in sequence:

a first surface with a first angle to said axis for guiding a cutting tool into initial cutting engagement with and partly through a wall of a casing;

a second surface substantially parallel to said axis for guiding the cutting tool during cutting of the wall of the casing;

a third surface with a third angle to said axis for guiding the cutting tool further out of the casing; and,

a fourth surface with a fourth angle to said axis for kicking said cutter out through said casing wall, said fourth angle being greater than the third angle.

14. A whipstock according to claim 13, wherein said first and fourth angles are substantially equal.

15. A whipstock according to claim 13 or claim 14, wherein said third angle is less than said first angle.

16. A whipstock according to any of claims 13 to 15, comprising a fifth surface following the fourth surface and having a fifth angle to said axis.

17. A whipstock according to claim 16, wherein said third and fifth angles are substantially equal.

18. A whipstock substantially as described with reference to the accompanying drawings.

The Patent Office

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Application No:	GB 9708956.9	**Examiner:**	E.L. Rendle
Claims searched:	1-6 and 11-18	**Date of search:**	27 June 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): E1F (FCU)

Int Cl (Ed.6): E21B

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X, P	GB 2 303 158 A	(RED BARON) see steep ramp 32 in figures 1 and 2 and page 10 line 27 to page 12 line 8.	1
X, P	GB 2 299 105 A	(TIW) see figures 8, 9a and 9 and page 22 lines 16-29.	1
X	US 5 484 021	(HAILEY) see whipstock in figures 2, 3, 5-9.	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
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